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Bioaccumulation of mercury in some organs of two fish species from the Sanandaj Gheshlagh Reservoir, Iran

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Original Article

Abstract

The purpose of this study was to monitor the concentrations of mercury in the edible muscle, gill, liver, and skin of common carp (Cyprinus carpio) and silver carp (Hypophthalmichthys molitrix), in the Sanandaj Gheshlagh Reservoir, Iran. Mercury concentrations were assayed using Shimadzu AA 6600 atomic absorption spectrophotometer, and the results were given as µg/g wet weight. The level of mercury in organs of silver carp was higher than in common carp. Moreover, the highest and lowest level of mercury has been accumulated in the gill and skin organs respectively. The results showed that the maximum allowable fish consumption rate for an adult person with mean 71.5 kg body weight were 21 g/day base on g/day based on mercury levels. In conclusion, results showed that the mercury concentrations in the edible muscle of both fish species are below levels of concern for human consumption.

KEYWORDS: Carps, Gills, Liver, Mercury, Iran

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Introduction

The metal contamination of aquatic ecosystems has emerged as a worldwide concern over the past years. Due to their toxicity and long persistence, the addition of metals into the human food chain can introduce the potentially severe health hazards.[1] Metals are categorized into essential and non-essential types. The copper and zinc are essential for maintaining cellular function, enzymatic activities and other biological processes, and hence, the so-called essential metals. Other metals such as mercury and cadmium have no a well-known biological function and exert their toxicity by competing with essential metals to active enzyme or membrane protein sites.[2] Mercury is known as toxic metals for their negative effects on the function of kidney, nervous, and immune systems. Furthermore, long exposure to mercury can permanently damage the brain, kidney, and decline the natural progress of the fetuses and young children.[3]

Fish serve as one of the main sources of protein for humans. It is rich of omega-3 polyunsaturated fatty acids, which can reduce cholesterol level.[4] Fish can easily uptake pollutants from the environment, either from the water or the food. Studies on metals pollution using fish are enormous.[1,5,6] The accumulation of metals in the organs of a fish depends on various factors. Amongst others, the fish age, gender, size, environmental conditions (e.g., water

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hardness, temperature, and pH), metabolic rate, and exposure duration are some examples.[7-9]

The Sanandaj Gheshlagh Reservoir (SGR), Iran, is one of a few fishing sites in the area that supplies a major part of the Sanandaj's demand for fish. However, its safety in providing a healthier food supply is subject to pollution from two external sources; (i) the chemical fertilizers and pesticides from agricultural use on the farms surrounded the reservoir, and (ii) the crude oil and other petroleum products transported by truck from Iraq to Iran and vice versa. Both sources can potentially release a substantial amount of contaminant such as mercury into the SGR. Therefore, the objective of this study was to determine the levels of mercury in edible muscle, gill, liver, and skin organs of two fish species captured daily in the SGR. This can be used to assess whether the mercury levels meet the local and international requirements. We also aim to study whether the species of the fish, their length, weight, and sex are related to mercury accumulation.

Materials and Methods

The Gheshlagh reservoir (35°25′-35°30′ N; 46°57′-47°30′ E) is located 12 km away from Sanandaj city in the west of Iran. The Gheshlagh reservoir was in principal built to supply drinking water for Sanandaj city (main water resources for household use); and the irrigation water for the downstream lands. The average annual temperature of the water ranges from 5.2 °C (January) to 25 °C (August).

Fish samples were caught from random catches in the SGR during October-December, 2013 and carried to the laboratory by a thermos flask with ice. A total of 23 fish was assessed for mercury in the edible muscle, gill, liver, and skin organs. The collection included common carp (males = 5 and females = 8) and silver carp (males = 6 and females = 4). In the laboratory, they were immediately dissected using a stainless steel dissection instrument. Muscle samples were separated from below the dorsal fin without skin.[1] Average of total length and total weight of sampled fish was measured 30.4 (± 4.8) cm and 533.6 (± 175.7) g for common carp; and 39.5 (± 6.8) cm, 34.6 (± 6.8) cm and 664.2 (± 232.1) g for silver carp, respectively. Approximately 1 g wet weight (WW) of gills, skin, and edible muscle, and liver from each sample were dissected, washed with distilled water, and accurately weighed into 150-ml erlenmeyer flasks. To each sample, 10 ml nitric acid (65%) was added. Samples were left overnight in order to digest slowly. Afterward, 5 ml perchloric acid (70%) added to each sample.[10,11] Digestion was performed on a hot plate (sand bath) at 150 °C before diluting the samples with 25 ml deionized water. The concentration of mercury was measured using a Shimadzu AA 6600 atomic absorption spectrophotometer by cold vapor. For mercury metal, we obtained the detection limits as 0.04. Moreover, the mean recovery for mercury was 97.3%.

Statistical analysis was performed using SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL, USA). Data were tested for normality using a Kolmogorov-Smirnov test. Data were normally distributed; therefore, a parametric test was used for analysis. The one-way analysis of variance (ANOVA) was performed to establish the statistically significant differences in the concentration of mercury metal between the organs. Student's t-test was used for group comparison between two species. Pearson correlation (r) was used to determine the correlation between the levels of accumulated mercury metal in the edible muscle, gills, liver, and skin organs of common carp and silver carp and their biometric features (total length and total weight). The mercury concentrations in organs were expressed as microgram per gram WW. Values are given in means ± standard deviation.

Daily consumption limits were obtained using the following equation. It shows allowable daily consumption of mercury contaminated fish based on a contaminant's carcinogenicity, expressed in

kilograms of fish consumed per day:[12]

$$CR_{lim} = \frac{RfD \times BW}{C_m}$$

Where CR_{lim} is maximum allowable fish consumption rate (kilograms/day); RfD is reference dose (0.1 µg/kg/day for mercury); BW is consumer body weight (kilograms); and C_m is measured concentration of chemical contaminant m in a given species of fish (milligrams per kilogram).

The consumption limit is determined in part by the size of the meal consumed. We assumed the meal size as 0.227. The following equation can be used to convert daily consumption limits to the number of allowable meals per month:

$$CR_{mm} = \frac{CR_{lim} \times T_{ap}}{MS}$$

CR_{mm} is maximum allowable fish consumption rate (meals/month); CR_{lim} is maximum allowable fish consumption rate (kilograms/day); MS is meal size (0.227 kg fish/meal); and Tap is time averaging period (365.25 days/12 months = 30.44 days/month).

Results and Discussion

The mean concentration of mercury in the organs of liver, gill, edible muscle, and skin of two fish species (common carp and silver carp) is presented in table 1. From table 1, it can be seen that for both fish species, the highest and lowest level of mercury has been accumulated in the gill and skin organs respectively. One reason for high level of metal concentrations in the gill organs of fish samples can be due to absorption and adsorption as the main sites of metallothionein (MT) production and metal retention, after making direct contact with the surrounding waters.[13] MT is low-molecular-weight proteins with many sulfhydryl groups binding a variety of metals such as copper, zinc, cadmium, and mercury, showing a strong affinity toward certain essential and non-essential metals.[2] In contrast, one reason may be due to this fact that the skin involve in lower metabolic activities in accumulating metals. Fish skin typically provides less surface area, a thicker and less permeable diffusion barrier, slower transport of water to the exchange surface, less blood flow, and no countercurrent flow of water and blood.[14]

The mercury is a persistent toxic for humans and wildlife with well-known negative neurological and reproductive effects. Hence, the level of mercury must be monitored in food chains to avoid its negative consequences.[15] The concentrations of mercury in the organs ranged from 0.1 to 0.3 µg/g WW for common carp and from 0.2 to 0.5 µg/g WW for silver carp. These levels were lower than those reported by 6. Majnouni et al.[6] in same fish species in Zarivar

Table 1. Mercury concentrations (mean ± standard deviation) in the organs of common carp and silver carp

Species/sex	Organs			
	Gill	Liver	Muscle	Skin
Common carp				
Male	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1
Female	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1
Mean	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1
P sex	0.05	NS	NS	NS
Silver carp				
Male	0.3 ± 0.1	0.3 ± 0.2	0.3 ± 0.1	0.1 ± 0.1
Female	0.6 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.2 ± 0.1
Mean	0.5 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.2 ± 0.1
P sex	0.050	NS	NS	NS
P species*	0.020	NS	0.020	NS

* P value for Student's t-test to compare between species; NS: not significant at P > 0.050

Lake known as an area with high source of pollutions such as wastewater discharge, chemical fertilizers, and pesticides from farmlands. Mercury concentrations in the common carp (0.3-0.1 µg/g) and silver carp (0.4-0.2 µg/g) edible muscles and skin were lower than the maximum acceptable concentrations established by Food and Agriculture Organization and World Health Organization (i.e., 0.5 µg/g on WW).[16] However, it should be noted that the Environmental Protection Agency has defined the published maximum acceptable concentration of mercury by 0.3 µg/g on WW basis.[17] The results presented in table 1 show that apart from the edible muscle organ of silver carp, the mean of accumulated mercury level was in general lower than this threshold in all organs of both fish species. In similar study by Khoshnamvand et al.[18] from July to December 2009 in SGR reported that the T-mercury in the muscle organs (0.31-0.36 µg/g on WW) was higher than this standard.

Assessments of the human health risks associated with the consumption of mercury content contaminated fish are given according to daily (kg/day) and monthly (meals/month) limits for the 3-75 years old population demographic in table 2. The results of this study showed that the maximum allowable fish consumption rate for an adult person with mean body weight of 71.5 kg was 21 g/day based on mercury levels. The maximum allowable consumption rate has been reported equal to 8-56 g/day for cultured fish from Persian Gulf in Iran base on the Hg content.[12] Kannan et al.[19] found that consuming fish from South Florida Estuaries at rates > 70 g/day was estimated to be hazardous to human health. We found that the level of mercury in the muscle of common carp and silver carp (0.3-0.4 µg/g WW) was lower than the reported mercury in the same fish species (1.1-0.8 µg/g WW) from the Zarivar lake.[6]

The analysis of Pearson correlation coefficients of length, weight and metal concentrations in two fish species showed that the significant association between total length, weight and mercury concentrations ($P < 0.050$; Table 3). The results of our study also showed that the mercury concentrations in silver carp were in general higher than what we observed in common carp. We studied two fish species of Cyprinid family. Based on our findings, we may conclude that different species of this family may follow different foraging strategy. However, with a few exceptions (mercury in the gill of both species and mercury in the muscle of silver carp), we found the differences between male and female fish was statistically non-significant (t-test, $P > 0.050$).

Table 2. Maximum allowable fish consumption rate according to the metals content

Age (year)	Average body weight for male and female (kg)	Maximum allowable fish consumption rate (kg/day) mercury	Maximum allowable fish consumption rate (meals/month) mercury
3-6	11.6	0.0033	0.4425
6-9	25.0	0.0071	0.9520
9-12	36.0	0.0102	1.3677
12-15	50.6	0.0144	1.9309
15-18	61.2	0.0174	2.3332
18-25	67.2	0.0192	2.5746
25-35	71.5	0.0204	2.7355
35-45	74.0	0.0211	2.8294
45-55	74.5	0.0212	2.8428
55-65	73.4	0.0209	2.8026
65-75	70.7	0.0202	2.7087

It is believed that the sex-related differences in metal concentration may cause by a combination of some factors, such as dietary preferences, physiological metabolism in relation to stage in the reproductive cycle or foraging behavior. In our study, sex did not exert a significant effect on metal concentrations in most organs of both fish species. However, Al-Yousuf et al.[7] found higher average zinc and cadmium concentrations in the liver, skin, and muscle of female fish compared to male fish. In contrast, metals accumulated in both fish species were significant differences among the organs of liver, gill, edible muscle, and skin (one-way ANOVA, $P < 0.001$; Table 4). Al-Yousuf et al.[7] and Usero et al.[20] reported that the differences in zinc and cadmium concentrations of the organs might be a result of their capacity to induce production of metal-binding proteins such as MT.

Table 3. Correlation of size, weight, and metals levels in the muscle of common carp and silver carp

Species	Mercury	Size	Weight
Common carp			
Mercury	1	0.08	0.16
Size			0.50
Weight			1
Silver carp			
Mercury	1	0.64*	0.65*
Size		1	0.97**
Weight			1

* Correlation is significant at the 0.050 level; ** Correlation is significant at the 0.050 level

Table 4. Statistical analysis of mercury levels in the edible muscle, gill, liver, and skin of both species

Fish species	One-way ANOVA	
	F	P
Common carp	7.3	< 0.001
Silver carp	7.9	< 0.001

P significance level; NS: Not significant; ANOVA: Analysis of variance

Conclusion

This study reveals that the highest and lowest level of mercury has been accumulated in the gill and skin organs respectively. The statistical analysis indicated that the mercury concentrations differed significantly among liver, gill, edible muscle, and skin in common carp and silver carp. Metal concentrations in both fish species were higher in silver carp than in common carp. In general, results shows metal concentrations in the edible muscle of both fish species are below levels of concern for human consumption. In conclusion, the accumulation and uptake of mercury in the organs of fish depends on the organs, genders, and species.

Conflict of Interests

Authors have no conflict of interests.

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